Recent developments of high field ESR systems in Kobe

To cite this article: H Ohta et al 2006 J. Phys.: Conf. Ser. 51 611

View the article online for updates and enhancements.

Related content
- Development and application of high field and high pressure ESR system
  T Sakurai, A Taketani, T Tomita et al.
- ESR Measurements at Temperatures around 0.1 K
  Hidetaro Abe and Kei-ichi Koga
- Development of a multi-frequency ESR system with high sensitivity
  H Yashiro, T Kashiwagi, M Horitani et al.

Recent citations
- Dzyaloshinsky–Moriya Interaction and the Ground State in S = 3/2 Perfect Kagome Lattice Antiferromagnet KC3(OH)6(SO4)2 (Cr-Jarosite) Studied by X-Band and High-Frequency ESR
  Susumu Okubo et al
- High-field ESR Measurements of YCrO3
  Shohei Ikeda et al
- Hitoshi Ohta et al
Recent developments of high field ESR systems in Kobe

H Ohta\textsuperscript{a,b,c,d}, M Tomoo\textsuperscript{b}, S Okubo\textsuperscript{a}, T Sakurai\textsuperscript{c}, M Fujisawa\textsuperscript{d}, T Tomita\textsuperscript{a}, M Kimata\textsuperscript{b}, T Yamamoto\textsuperscript{a}, M Kawauchi\textsuperscript{e} and K Kindo\textsuperscript{f}

\textsuperscript{a}Molecular Photoscience, Research Center, Kobe University, 1-1 Rokkodai, Nada, Kobe 657-8501, Japan
\textsuperscript{b}The Graduate School of Science and Technology, Kobe University, 1-1 Rokkodai, Nada, Kobe 657-8501, Japan
\textsuperscript{c}Center for Supports to Research and Education Activities, Kobe University, 1-1 Rokkodai, Nada, Kobe 657-8501, Japan
\textsuperscript{d}Department of Frontier Research and Technology, Kobe University, 1-1 Rokkodai, Nada, Kobe 657-8501, Japan
\textsuperscript{e}High Magnetic Field Laboratory, KYOKUGEN, Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan
\textsuperscript{f}Institute for Solid State Physics, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwacity, Chiba 277-8581, Japan

hohta@kobe-u.ac.jp

Abstract. The magnetic field of the high field ESR system in Kobe University has been extended to 55 T by using a new non-destructive pulse magnet and the 300 kJ (10kV) capacitor bank. The properties of new 55 T pulse magnet are reported. As an example of its application, the high field ESR measurement of a quantum spin system CsCuCl\textsubscript{3} for H//a will be shown.

1. Introduction
Recently, the high field magnetic phase of quantum spin systems such as NH\textsubscript{4}CuCl\textsubscript{3}, \cite{1} have attracted much attention in connection with the field-induced antiferromagnetic ordering and the magnetization plateaux. The magnetization measurement is a powerful method to study the ground state and the magnetic phase transition. However, the magnetic resonance and the diffraction methods such as NMR, ESR, the neutron and the X-ray diffraction measurements are often used to investigate the magnetic and energy structures, whose investigations are not possible by the magnetization measurement. Especially, ESR measurement can study the energy structures in different magnetic phases with high resolution under the pulsed magnetic field. Such examples can be found in reference \cite{2}. The high field ESR system in Kobe has been extended to the high magnetic field, the wide frequency range and the high pressure range \cite{3-5}. A few years ago the 300 kJ capacitor bank was moved from ISSP, University of Tokyo, and we prepared a new power supply for the bank during the installation. Then, a new pulsed magnet “D001” for the 300 kJ capacitor bank is made, and the high...
field ESR measurement up to 55 T is achieved. In this paper we will report our new high field ESR system equipped with 55 T magnet and its application to a quantum spin system CsCuCl₃.

2. High field ESR system in Kobe

Our pulsed magnetic field is generated by the discharge from the capacitor bank. Three different capacitor banks installed in Kobe University are shown in Table 1. As the resistance of the pulsed magnet is proportional to the number of winding layers, higher maximum voltage of the capacitor bank is advantageous to obtain higher current for the higher field. Therefore, the maximum voltage 10.0 kV for 300 kJ bank is obtained by connecting two capacitor banks with the maximum voltage 5.0 kV in series. The new pulsed magnet D001 is made by “Kindo” winding method as shown in Figure 1(a). D001 has following features; 1) continuous terminal processing around a bobbin, 2) the use of the high strength maraging steel for the supporting ring, 3) the use of CuAg wire which has high tensile strength, 4) the rapid cooling time by the optimum thickness of the maraging steel and 5) non-destructive magnet. The pulsed magnet D001 is cooled by the liquid nitrogen and it can generate the maximum field of 55 T within the inner diameter of 21 mm by the charging voltage of 8.5 kV. Figure 1(b) shows the resistance of the magnet as a function of time after the generation of the pulsed magnetic field. As the resistance of the magnet is related to its temperature, it is possible to estimate the cooling time from Figure 1(b). It shows that only 15 minutes interval is required for the next pulsed magnetic field even after the 55 T generation. Our pulse field system is described in reference [4]. We use the transmission method for the ESR measurement. The light from the light source is guided through the light pipe to the sample, which is located at the center of the magnet. The transmitted light is detected by the InSb detector. The light sources in Kobe cover the frequency range from 30 GHz to 3 THz. The details of our high field ESR system can be found in references [3, 4, 6, 7]. The aim in Kobe is to add other extreme condition to high field ESR. High field ESR measurements under high pressure can be performed using our transmission type pressure cell. The details of our high pressure ESR system are described in reference [8], and its recent achievement up to 1 GPa can be found in a separate paper of this conference [9]. In the following section, we will show our recent experimental results of the quantum spin system CsCuCl₃ obtained by our high field ESR.

<table>
<thead>
<tr>
<th>Energy</th>
<th>Voltage</th>
<th>Capacitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 kJ</td>
<td>23 kV</td>
<td>3.0 kV</td>
</tr>
<tr>
<td>100 kJ</td>
<td>100 kJ</td>
<td>3.0 kV</td>
</tr>
<tr>
<td>300 kJ</td>
<td>300 kJ</td>
<td>10.0 kV</td>
</tr>
</tbody>
</table>

Figure 1. (a) Cross section of the pulsed magnet D001. (b) The resistance profiles of D001 pulse magnet as a function of time after the generation of the pulsed magnetic field.
3. High field ESR measurements of a quantum spin system CsCuCl$_3$

CsCuCl$_3$ belongs to the ABX$_3$ type structure and it has ferromagnetic Cu$^{2+}$ chains along the $c$-axis and forms the antiferromagnetic triangular lattice in the $c$-plane. Below 10.5 K, the spins form the 120° structure in the $c$-plane as well as an incommensurate helical structure along the $c$-axis due to the competition between the ferromagnetic exchange interaction and the Dzyaloshinski-Moriya interaction [10]. It is well known that the quantum-fluctuation-induced magnetic transition from the umbrella structure to the collinear structure occurs at 12.5T for H/$c$ [11]. On the other hand, an incommensurate-commensurate (IC-C) transition was found in the field region 11-17 T for H/$c$ by the neutron measurements under the pulsed magnetic field [12]. The changes of the ESR modes in connection with the IC-C transition was found in the field region 11-17 T for H/$c$ by the neutron measurements under the pulsed magnetic field [12]. The changes of the ESR modes in connection with the IC-C transition was found in the field region 11-17 T for H/$c$ by the neutron measurements under the pulsed magnetic field [12]. The changes of the ESR modes in connection with the IC-C transition was found in the field region 11-17 T for H/$c$ by the neutron measurements under the pulsed magnetic field [12].

The high field ESR measurements of CsCuCl$_3$ for H/$a$ have been performed up to 50 T in the frequency range from 30 GHz to 240 GHz. Figure 2(a) and (b) show the ESR spectra at 4.2 K for H//$a$. Minor absorption lines are indicated by arrows. In the frequency range from 30 GHz to 240 GHz above H, there is no absorption line, which can be related to an anomaly of the relative sound velocity at 33.7 T and 1.5 K for H/$c$ in the ultrasonic measurements under the high field [16]. Here, the high field ESR measurements of CsCuCl$_3$ for H/$a$ have been performed up to 50 T in the frequency range from 30 GHz to 240 GHz. Figure 2(a) and (b) show the ESR spectra at 4.2 K for H/$a$. Minor absorption lines are indicated by arrows. In the frequency range from 30 GHz to 240 GHz above H, there is no absorption line, which can be related to an anomaly of the relative sound velocity at 33.7 T and 1.5 K for H/$c$ in the ultrasonic measurements under the high field [16]. Here, the high field ESR measurements of CsCuCl$_3$ for H/$a$ have been performed up to 50 T in the frequency range from 30 GHz to 240 GHz. Figure 2(a) and (b) show the ESR spectra at 4.2 K for H/$a$. Minor absorption lines are indicated by arrows. In the frequency range from 30 GHz to 240 GHz above H, there is no absorption line, which can be related to an anomaly of the relative sound velocity at 33.7 T and 1.5 K for H/$c$ in the ultrasonic measurements under the high field [16].

4. Summary
By the installation of the 10 kV, 300 kJ capacitor bank, we are now able to achieve the ESR measurement under the pulsed magnetic fields up to 50 T. The changes of ESR modes in CsCuCl\(_3\) among the magnetic phase transitions at \(H_{c1}, H_{c2}, H_s\) for \(H//a\) was investigated by our new high field ESR system. Detailed frequency dependence measurements in high magnetic field showed the high field ESR mode toward \(H_s\).

Acknowledgements
The authors are grateful to Prof. N. Miura for providing the 300 kJ capacitor bank from ISSP The authors would like to thank Prof. M. Hagiwara for the arrangement to use the High Magnetic Field Laboratory in Osaka. This work was partly supported by Grant-in-Aid for Scientific Research on Priority Areas “High Field Spin Science in 100T” (No. 451) from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan and Grant-in-Aid for Scientific Research (B) 16340106 from the Japan Society for the Promotion of Science (JSPS).

References
[9] Sakurai T et al., J. Phys:Conference Series, in these proceedings